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APPLICATION FOR UNITED STATES LETTERS PATENT

for

**METHOD AND APPARATUS FOR DISCRIMINATING
AND COUNTING DOCUMENTS**

by

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METHOD AND APPARATUS FOR DISCRIMINATING
AND COUNTING DOCUMENTS

Cross-Reference to Related Applications

pt

This application claims the benefit of copending United States Provisional Patent
5 Applications Serial Nos. 60/018,563 filed May 29, 1996 for a "Method and Apparatus
for Document Identification and Authentication"; 60/034,954 filed January 16, 1997
for a "Method and Apparatus for Document Processing"; and ~~60/034,954~~ ^{60/038,340} filed
February 27, 1997 for a "Two Pocket Currency Discriminator".

pt

This application is a continuation-in-part of pending United States Patent
10 application Serial No. 08/573,392 filed December 15, 1995 for a "Method and
Apparatus for Discriminating and Counting Documents", ^{now U.S. patent No. 5,790,697} United States Patent
application Serial No. 08/573,392 is a continuation-in-part of the following United
States Patent applications:

pt

15 pending application Serial No. 08/399,854 filed March 7, 1995 for a "Method
and Apparatus For Discriminating and Counting Documents"; ^{now U.S. patent No. 5,875,259}
pending application Serial No. 08/394,752 filed February 27, 1995 for a
"Method of Generating Modified Patterns and Method and Apparatus
for Using the Same in a Currency Identification System"; ^{now U.S. patent No. 5,724,438}
20 pending application Serial No. 08/362,848 filed December 22, 1994, for a
"Method And Apparatus For Discriminating and Counting Documents"; ^{now U.S. patent No. 5,870,487}
pending application Serial No. 08/340,031 filed November 14, 1994, for a
"Method And Apparatus For Discriminating and Counting Documents"; ^{now U.S. patent No. 5,815,592}
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pt
25 pending application Serial No. 08/317,349 filed October 4, 1994, for a
"Method And Apparatus For Authenticating Documents Including
Currency"; ^{now U.S. patent No. 5,640,463}
✓ pending application Serial No. 08/287,882 filed August 9, 1994 for a "Method
and Apparatus for Document Identification"; ^{now U.S. patent No. 5,652,802}
pending application Serial No. 08/243,807 filed May 16, 1994, for "Method
And Apparatus For Currency Discrimination"; ^{now U.S. patent No. 5,633,949} and
30 pending application Serial No. 08/226,660 filed April 12, 1994, for "Method
And Apparatus For Currency Discrimination".

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United States patent application Serial No. 08/399,854 is a continuation-in-part of United States patent applications Serial No. 08/394,752, Serial No. 08/340,031, and Serial No. 08/287,882.

5 United States patent application Serial No. 08/394,752 is a continuation-in-part of United States patent application Serial No. 08/340,031 and United States patent application Serial No. 08/127,334 filed September 27, 1993, for a "Method and Apparatus for Currency Discrimination and Counting", now issued as United States Patent No. 5,467,405.

10 United States patent application Serial No. 08/362,848 is a continuation-in-part of pending United States patent application Serial No. 08/340,031.

United States patent application Serial No. 08/340,031 is a continuation-in-part of United States patent application Serial No. 08/243,807 and United States patent application Serial No. 08/207,592 filed March 8, 1994 for a "Method and Apparatus for Currency Discrimination", now issued as United States Patent No. 5,467,406.

15 United States patent application Serial No. 08/287,882 is a continuation-in-part of United States patent application Serial No. 08/207,592, United States patent application 08/127,334 and abandoned United States patent application 08/219,093 filed on March 29, 1994, for a "Currency Discriminator and Authenticator".

20 United States patent application Serial No. 08/243,807 is a continuation-in-part of United States patent applications Serial No. 08/219,093 and Serial No. 08/127,334.

United States patent application Serial No. 08/226,660 is a continuation-in-part of United States patent application Serial No. 08/127,334.

Abandoned United States patent application Serial No. 08/219,093 is a continuation-in-part of United States patent application Serial No. 08/127,334.

25 United States patent application Serial No. 08/207,592, issued as United States Patent No. 5,467,406, is a continuation-in-part of United States patent application Serial No. 08/127,334.

30 United States patent application Serial No. 08/127,334, issued as United States Patent No. 5,467,405, is a continuation of United States patent application Serial No. 07/885,648, filed on May 19, 1992, and issued as United States Patent No. 5,295,196, for a "Method and Apparatus for Currency Discrimination and Counting," which is a continuation-in-part of abandoned United States patent application Serial No.

07/475,111, filed February 5, 1990, for a "Method and Apparatus for Currency Discrimination and Counting."

FIELD OF THE INVENTION

The present invention relates, in general, to currency identification. More specifically, the present invention relates to an apparatus and method for receiving a stack of currency bills, rapidly discriminating the denomination and/or authenticating the genuineness the bills in the stack and re-stacking the bills.

BACKGROUND OF THE INVENTION

Machines that are currently available for simultaneous scanning and counting of documents such as paper currency are relatively complex and costly, and relatively large in size. The complexity of such machines can also lead to excessive service and maintenance requirements. These drawbacks have inhibited more widespread use of such machines, particularly in banks and other financial institutions where space is limited in areas where the machines are most needed, such as teller areas. The above drawbacks are particularly difficult to overcome in machines which offer much-needed features such as the ability to scan bills regardless of their orientation relative to the machine or to each other, and the ability to authenticate genuineness and/or denomination of the bills.

Currency discrimination systems typically employ either magnetic sensing or optical sensing for discriminating among different currency denominations. Magnetic sensing is based on detecting the presence or absence of magnetic ink in portions of the printed indicia on the currency by using magnetic sensors, usually ferrite core-based sensors, and using the detected magnetic signals, after undergoing analog or digital processing, as the basis for currency discrimination. A variety of currency characteristics can be measured using magnetic sensing. These include detection of patterns of changes in magnetic flux, patterns of vertical grid lines in the portrait area of bills, the presence of a security thread, total amount of magnetizable material of a bill, patterns from sensing the strength of magnetic fields along a bill, and other patterns and counts from scanning different portions of the bill such as the area in which the denomination is written out.

The more commonly used optical sensing techniques, on the other hand, are based on detecting and analyzing variations in light reflectance or transmissivity characteristics occurring when a currency bill is illuminated and scanned by a strip of focused light. The subsequent currency discrimination is based on the comparison of sensed optical characteristics with prestored parameters for different currency denominations, while accounting for adequate tolerances reflecting differences among individual bills of a given denomination. A variety of currency characteristics can be measured using optical sensing. These include detection of a bill's density, color, length and thickness, the presence of a security thread and holes, and other patterns of reflectance and transmission. Color detection techniques may employ color filters, colored lamps, and/or dichroic beamsplitters.

In addition to magnetic and optical sensing, other techniques of detecting characteristic information of currency include electrical conductivity sensing, capacitive sensing (such as for watermarks, security threads, thickness, and various dielectric properties) and mechanical sensing (such as for size, limpness, and thickness).

A major obstacle in implementing automated currency discrimination systems is obtaining an optimum compromise between the criteria used to adequately define the characteristic pattern for a particular currency denomination, the time required to analyze test data and compare it to predefined parameters in order to identify the currency bill under scrutiny, and the rate at which successive currency bills may be mechanically fed through and scanned. Even with the use of microprocessors for processing the test data resulting from the scanning of a bill, a finite amount of time is required for acquiring samples and for the process of comparing the test data to stored parameters to identify the denomination of the bill.

It has been found that scanning U.S. bills of different denominations along a central portion thereof provides scanning patterns sufficiently divergent to enable accurate discrimination between different denominations. Such a discrimination device is disclosed in U.S. Pat. No. 5,295,196.

In some currency discriminators bills are transported, one at a time, past a discriminating unit. As the bills pass the discriminating unit, the denomination of each bill is determined and a running total of each particular currency denomination and/or of the total value of the bills that are processed is maintained.

Therefore, there is a need for an apparatus which is capable of discriminating among, authenticating, and counting bills of several currency denominations at a high speed with a high degree of accuracy into a plurality of output receptacles that overcomes the problems associated with transporting and evaluating bills in their long dimension.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved method and apparatus for identifying, authenticating, and counting currency bills comprising a plurality of currency denominations.

10 It is an object of the present invention to provide an improved method and apparatus for discriminating among currency bills comprising a plurality of currency denominations.

It is another object of this invention to provide an improved method and apparatus of the above kind which is capable of efficiently discriminating among, authenticating, and counting bills of several currency denominations at a high speed and with a high degree of accuracy.

15 It is another object of this invention to provide an improved method and apparatus of the above kind which is capable of efficiently discriminating among, authenticating, and counting bills of several currency denominations at a high speed while the bills are being transported in the direction of its narrow dimension into a plurality of output receptacles.

A related object of the present invention is to provide such an improved currency discrimination and counting apparatus which is compact, economical, and has uncomplicated construction and operation.

25 Another object of this invention is to provide such an improved currency scanning and counting machine that is relatively inexpensive to manufacture and maintain, and which also facilitates service and maintenance. In this connection, a related object of the invention is to provide such a machine having a relatively small number of parts, and in which most of the parts are arranged in a manner to have a long operating life with little or no maintenance.

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Other objects and advantages of the invention will become apparent upon reading the following detailed description in conjunction with the accompanying drawings.

In accordance with one embodiment of the present invention, the foregoing
 5 objectives are realized by providing a currency evaluating device for receiving a stack of currency bills, rapidly counting, authenticating and discriminating the bills in the stack, and then re-stacking the bills. This device includes an input receptacle for receiving a stack of currency bills to be discriminated, a discriminating unit for determining the currency bills by denomination, an authenticating unit for determining
 10 the genuineness of the bills, a plurality of output receptacles for receiving the currency bills at a rate in excess of about 800 bills per minute after they have been discriminated, and a transport mechanism for transporting the currency bills, one at a time, from the input receptacle past the discriminating unit and to one of a number of output receptacles. For example, the evaluating device may include six output receptacles.
 15 The evaluating device may comprise one or more counters keeping track of the value of bills discriminated.

In accordance with one embodiment of the present invention, the objectives enumerated above are achieved by scanning a document along one or more segments, generating one or more scanned patterns therefrom, and comparing the one or more
 20 scanned patterns to one or more master patterns associated with scans along corresponding segments of genuine documents. In an other embodiment, a first and a second characteristic information from a scanned bill are compared to respective scanned patterns to indicate the genuineness of the bill. According to the present invention, bills are fed in and scanned across their narrow dimension.

25 In one embodiment, the invention is particularly adapted to be implemented with a system programmed to track each identified currency identity so as to conveniently present aggregate totals for bills that have been identified at the end of a scan run. One embodiment counts bills and transporting the bills about their narrow dimension across a scanhead and into one of a plurality of output receptacles where the
 30 sensed and counted bills are collected. In one embodiment, a scanhead of the present invention operates in conjunction with an optical encoder which is adapted to initiate the capture of a predefined number of reflectance data samples when a bill (and, thus,

the indicia or pattern printed thereupon) moves across a coherent strip of light focused by the scanhead.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a is a functional block diagram of the currency evaluating machine of
5 FIG. 1 illustrating a scanhead arranged on each side of a transport path;

FIG. 1b is a functional block diagram of the currency evaluating machine illustrating a scanhead arranged on a single side of a transport path;

FIG. 1c is a functional block diagram of the currency evaluating machine similar to that of FIGs. 1a-1b illustrating the employment of a second characteristic
10 detector;

FIG. 2a is a side view of one embodiment of a document authenticating system according to the present invention;

FIG. 2b is a top view of the embodiment of FIG. 2a along the direction 2B;

FIG. 2c is a top view of the embodiment of FIG. 2a along the direction 2C;

FIG. 3 is a functional block diagram illustrating one embodiment of a document
15 authenticating system according to the present invention;

FIG. 4 is a top view of thread sensors of a document discriminating/
authenticating system;

FIG. 5 is a diagrammatic perspective illustration of the successive areas
20 scanned during the traversing movement of a single bill across an optical sensor according to one embodiment of the present invention;

FIG. 6 is a perspective view of a bill and one area to be optically scanned on the bill;

FIG. 7 is a diagrammatic side elevation view of the scan area to be optically
25 scanned on a bill according to embodiments of the present invention;

FIG. 8a is a perspective view of a bill showing the preferred area of a first surface to be scanned by one of the two scanheads employed in one embodiment of the present invention;

FIG. 8b is another perspective view of the bill in FIG. 8a showing the preferred area of a second surface to be scanned by the other of the scanheads employed in one embodiment of the present invention;

FIG. 9 is a perspective view of a currency evaluating machine according to one
5 embodiment of the present invention;

FIG. 10 is a side view of an evaluation device depicting various transport rolls in side elevation according to one embodiment of the present invention;

FIG. 11 is a sectional side view taken across a currency pathway depicting a bill in the region of an evaluating mechanism according to one embodiment of the
10 present invention;

FIG. 12 is a sectional bottom view depicting a portion of a transport plate illustrating H-shaped leaf springs in conjunction with passive rolls according to one embodiment;

FIG. 13 is a top view of a machine depicting various shafts according to one
15 embodiment of the present invention;

FIG. 14 is a sectional side view taken across a currency pathway depicting a bill passing below a first follower plate according to one embodiment of the present invention;

FIG. 15 is a sectional side view taken across a currency pathway depicting a
20 bill passing below a second follower plate according to one embodiment of the present invention;

FIG. 16a is a side view of an evaluation device depicting various transport rolls in side elevation having three output receptacles according to one embodiment of the present invention;

FIG. 16b is a side view of an evaluation device depicting various transport rolls in side elevation having four output receptacles according to one embodiment of the present invention;

FIG. 16c is a side view of an evaluation device depicting various transport rolls in side elevation having six output receptacles according to one embodiment of the
30 present invention;

FIG 17a is a functional block diagram illustrating one embodiment of a document authenticator and discriminator;

FIG 17b is a functional block diagram illustrating another embodiment of a document authenticator and discriminator;

FIG. 18 is an end elevation of the upper support member which includes the upper scanhead, and the sectional view of the lower support member mounted beneath the upper support member according to one embodiment;

FIG. 19 is a section taken through the centers of both the upper and lower support members, along the long dimension of the lower support member according to one embodiment of the present invention;

FIG. 20 is a top plan view of an upper support member which includes an upper scanhead according to one embodiment;

FIG. 21 is a bottom plan view of an upper support member which includes an upper scanhead according to one embodiment; and

FIG. 22 is a diagrammatic illustration of the location of two auxiliary photo sensors relative to a bill passed thereover by the transport and scanning mechanism according to embodiments of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

According to one embodiment of the present invention, a currency discrimination system adapted to U.S. currency is described. Furthermore, while the embodiments below entail the scanning of currency bills, the system of the present invention is applicable to other documents as well. For example, the system of the present invention may be employed in conjunction with stock certificates, bonds, and postage and food stamps.

Referring now to FIGs. 1a and 9, there is shown one embodiment of a currency evaluating machine 10 according to the present invention. The machine 10 includes an input receptacle or bill accepting station 12 where stacks of currency bills that need to be identified and counted are positioned. Bills in the input receptacle are acted upon by a bill separating station 14 which functions to pick out or separate one bill at a time for being sequentially relayed by a bill transport mechanism 16 (FIG. 1a), according to a precisely predetermined transport path, between a pair of scanheads 18a, 18b where the currency denomination of the bill is scanned and identified. In one embodiment, bills are scanned and identified at a rate in excess of 800 bills per minute. According to another embodiment, bills are scanned at a rate in excess of 1000 bills per minute.

In the embodiment depicted in FIG. 1a, each scanhead 18a, 18b is an optical scanhead that scans for characteristic information from a scanned bill 17 which is used to identify the denomination of the bill. The scanned bill 17 is then transported to one of a plurality of output receptacles or bill stacking stations 20 where bills so processed
5 are stacked for subsequent removal.

Each optical scanhead 18a, 18b preferably comprises a pair of light sources 22 directing light onto the bill transport path so as to illuminate a substantially rectangular light strip 24 upon a currency bill 17 positioned on the transport path adjacent the scanhead 18. Light reflected off the illuminated strip 24 is sensed by a photodetector
10 26 positioned between the two light sources. The analog output of the photodetector 26 is converted into a digital signal by means of an analog-to-digital (ADC) converter unit 28 whose output is fed as a digital input to a central processing unit (CPU) 30.

Referring still to FIG. 1a, the bill transport path is defined in such a way that the transport mechanism 16 moves currency bills with the narrow dimension of the bills
15 being parallel to the transport path and the scan direction. As a bill 17 traverses the scanheads 18a, 18b, the light strip 24 effectively scans the bill across the narrow dimension of the bill. In the embodiment depicted, the transport path is so arranged that a currency bill 17 is scanned across a central section of the bill along its narrow dimension, as shown in FIG. 1a. Each scanhead functions to detect light reflected
20 from the bill as it moves across the illuminated light strip 24 and to provide an analog representation of the variation in reflected light, which, in turn, represents the variation in the dark and light content of the printed pattern or indicia on the surface of the bill. This variation in light reflected from the narrow dimension scanning of the bills serves as a measure for distinguishing, with a high degree of confidence, among a plurality of
25 currency denominations which the system is programmed to handle.

A series of such detected reflectance signals are obtained across the narrow dimension of the bill, or across a selected segment thereof, and the resulting analog signals are digitized under control of the CPU 30 to yield a fixed number of digital reflectance data samples. The data samples are then subjected to a normalizing routine
30 for processing the sampled data for improved correlation and for smoothing out variations due to "contrast" fluctuations in the printed pattern existing on the bill surface. The normalized reflectance data represents a characteristic pattern that is

unique for a given bill denomination and provides sufficient distinguishing features among characteristic patterns for different currency denominations.

In order to ensure strict correspondence between reflectance samples obtained by narrow dimension scanning of successive bills, the reflectance sampling process is preferably controlled through the CPU 30 by means of an optical encoder 32 which is linked to the bill transport mechanism 16 and precisely tracks the physical movement of the bill 17 between the scanheads 18a, 18b. More specifically, the optical encoder 32 is linked to the rotary motion of the drive motor which generates the movement imparted to the bill along the transport path. In addition, the mechanics of the feed mechanism ensure that positive contact is maintained between the bill and the transport path, particularly when the bill is being scanned by the scanheads. Under these conditions, the optical encoder 32 is capable of precisely tracking the movement of the bill 17 relative to the light strips 24 generated by the scanheads 18a, 18b by monitoring the rotary motion of the drive motor.

The outputs of the photodetectors 26 are monitored by the CPU 30 to initially detect the presence of the bill adjacent the scanheads and, subsequently, to detect the starting point of the printed pattern on the bill, as represented by the thin borderline 17a which typically encloses the printed indicia on currency bills. Once the borderline 17a has been detected, the optical encoder 32 is used to control the timing and number of reflectance samples that are obtained from the outputs of the photodetectors 26 as the bill 17 moves across the scanheads 18a, 18b.

FIG. 1b illustrates one embodiment of a currency evaluating machine 10 similar to that of FIG. 1a but has a scanhead on only a single side of the transport path. As illustrated in FIG. 1b, the transport mechanism 16 moves currency bills with a narrow dimensions being parallel to the transport path and the scan direction. FIGs. 1b and 4 illustrate bills oriented with their narrow dimension "W" parallel to the direction of movement and scanning.

Referring now to FIG. 1c, there is shown a functional block diagram illustrating one embodiment of a currency discriminating and authenticating system according to the present invention. The operation of the system of FIG. 1c is the same as that of FIG. 1a except as modified below. The machine 10 includes a bill accepting station 12 where stacks of currency bills that need to be identified, authenticated, and counted are

positioned. Accepted bills are acted upon by a bill separating station 14 which functions to pick out or separate one bill at a time for being sequentially relayed by a bill transport mechanism 16, according to a precisely predetermined transport path, across two scanheads 18 and 39 where the currency denomination of the bill is identified and the genuineness of the bill is authenticated.

In the embodiment depicted, scanhead 18 is an optical scanhead that scans for a first type of characteristic information from a scanned bill 17 which is used to identify the denomination of the bill. A second scanhead 39 scans for a second type of characteristic information from the scanned bill 17. While in the illustrated embodiment scanheads 18 and 39 are separate and distinct, it is understood that these may be incorporated into a single scanhead. For example, where the first characteristic sensed is intensity of reflected light and the second characteristic sensed is color, a single optical scanhead having a plurality of detectors, one or more without filters and one or more with colored filters, may be employed (U.S. Pat. No. 4,992, 860 incorporated herein by reference). The scanned bill is then transported to one of a plurality of output receptacles 20 where bills so processed are stacked for subsequent removal.

The optical scanhead 18 of the embodiment depicted in FIG. 1c comprises at least one light source 22 directing a beam of coherent light downwardly onto the bill transport path so as to illuminate a substantially rectangular light strip 24 upon a currency bill 17 positioned on the transport path below the scanhead 18. Light reflected off the illuminated strip 24 is sensed by a photodetector 26 positioned directly above the strip. The analog output of photodetector 26 is converted into a digital signal by means of an analog-to-digital (ADC) converter unit 28 whose output is fed as a digital input to a central processing unit (CPU) 30.

The second scanhead 39 comprises at least one detector 41 for sensing a second type of characteristic information from a bill. The analog output of the detector 41 is converted into a digital signal by means of a second analog to digital converter 43 whose output is also fed as a digital input to the central processing unit (CPU) 30.

While scanhead 18 in the embodiment of FIG. 1c is an optical scanhead, it should be understood that the first and second scanheads 18 and 39 may be designed

to detect a variety of characteristic information from currency bills. Additionally these scanheads may employ a variety of detection means such as magnetic or optical sensors. For example, the scanhead may employ a magnetoresistive sensor or a plurality of such sensors including an array of such sensors. Such a sensor or sensors
 5 may, for example, be used to detect magnetic flux. A magnetic sensor or sensors may be employed such as the Gradiometer available from NVE Nonvolatile Electronics, Inc., Eden Prairie, MN. For example, a magnetoresistive sensor may be employed to detect, for example, magnetic flux. Examples of magnetoresistive sensors are described in, for example, U.S. Pat. Nos. 5,119,025, 4,683,508, 4,413,296, 4,388,662,
 10 and 4,164,770. Additionally, other types of magnetic sensors may be employed of detecting magnetic flux such as Hall effect sensors and flux gates.

A variety of currency characteristics can be measured using magnetic sensing. These include detection of patterns of changes in magnetic flux (U.S. Pat. No. 3,280,974), patterns of vertical grid lines in the portrait area of bills (U.S. Pat. No.
 15 3,870,629), the presence of a security thread (U.S. Pat. No. 5,151,607), total amount of magnetizable material of a bill (U.S. Pat. No. 4,617,458), patterns from sensing the strength of magnetic fields along a bill (U.S. Pat. No. 4,593,184), and other patterns and counts from scanning different portions of the bill such as the area in which the denomination is written out (U.S. Pat. No. 4,356,473). An additional type of magnetic
 20 detection system is described in U.S. Pat. No. 5,418,458.

With regards to optical sensing, a variety of currency characteristics can be measured such as detection of density (U.S. Pat. No. 4,381,447), color (U.S. Pat. Nos. 4,490,846; 3,496,370; 3,480,785), length and thickness (U.S. Pat. No. 4,255,651), the presence of a security thread (U.S. Pat. No. 5,151,607) and holes (U.S. Pat. No.
 25 4,381,447), and other patterns of reflectance and transmission (U.S. Pat. No. 3,496,370; 3,679,314; 3,870,629; 4,179,685). Color detection techniques may employ color filters, colored lamps, and/or dichroic beamsplitters (U.S. Pat. Nos. 4,841,358; 4,658,289; 4,716,456; 4,825,246, 4,992,860 and EP 325,364).

Referring now to FIGs. 2a-2c, there is shown a side view of one embodiment
 30 of a document authenticating system according to an embodiment using ultraviolet light, a top view of the embodiment of FIG. 2a along the direction 2B, and a top view of the embodiment of FIG. 2a along the direction 2C, respectively. The evaluating

system of FIGs. 2a-2c may be employed, for example, as a second scanhead, such as scanhead 39 of FIG. 1c, to detect characteristic information to authenticate bills. An ultraviolet ("UV") light source 422 illuminates a document 424. Depending upon the characteristics of the document, ultraviolet light may be reflected off the document and/or fluorescent light may be emitted from the document. A detection system 426 is positioned so as to receive any light reflected or emitted toward it but not to receive any UV light directly from the light source 422. The detection system 426 comprises a UV sensor 428, a fluorescence sensor 430, filters, and a plastic housing. The light source 422 and the detection system 426 are both mounted to a printed circuit board 432. The document 424 is transported in the direction indicated by arrow A by a transport system (not shown). The document is transported over a transport plate 434 which has a rectangular opening 436 in it to permit passage of light to and from the document. In one embodiment of the present invention, the rectangular opening 436 is 1.375 inches (3.493 cm) by 0.375 inches (0.953 cm). To minimize dust accumulation onto the light source 422 and the detection system 426 and to prevent document jams, the opening 436 is covered with a transparent UV transmitting acrylic window 438. To further reduce dust accumulation, the UV light source 422 and the detection system 426 are completely enclosed within a housing (not shown) comprising the transport plate 434.

Referring now to FIG. 3, there is shown a functional block diagram illustrating one embodiment of a document evaluating system according to the present invention. FIG. 3 shows an UV sensor 442, a fluorescence sensor 444, and filters 446, 448 of a detection system such as the detection system 426 of FIG. 2. Light from the document passes through the filters 446, 448 before striking the sensors 442, 444, respectively. An ultraviolet filter 446 filters out visible light and permits UV light to be transmitted and hence to strike UV sensor 442. Similarly, a visible light filter 448 filters out UV light and permits visible light to be transmitted and hence to strike fluorescence sensor 444. Accordingly, UV light, which has a wavelength below 400 nm, is prevented from striking the fluorescence sensor 444 and visible light, which has a wavelength greater than 400 nm, is prevented from striking the UV sensor 442. In one embodiment the UV filter 446 transmits light having a wavelength between about 260 nm and about 380 nm and has a peak transmittance at 360 nm. In one embodiment, the visible light

filter 448 is a blue filter and preferably transmits light having a wavelength between about 415 nm and about 620 nm and has a peak transmittance at 450 nm. The above preferred blue filter comprises a combination of a blue component filter and a yellow component filter. The blue component filter transmits light having a wavelength
5 between about 320 nm and about 620 nm and has a peak transmittance at 450 nm. The yellow component filter transmits light having a wavelength between about 415 nm and about 2800 nm. Examples of suitable filters are UG1 (UV filter), BG23 (blue bandpass filter), and GG420 (yellow longpass filter), all manufactured by Schott. In one embodiment the filters are about 8 mm in diameter and about 1.5 mm thick.

10 The UV sensor 442 outputs an analog signal proportional to the amount of light incident thereon and this signal is amplified by amplifier 450 and fed to a microcontroller 452. Similarly, the fluorescence sensor 444 outputs an analog signal proportional to the amount of light incident thereon and this signal is amplified by amplifier 454 and fed to a microcontroller 452. Analog-to-digital converters 456
15 within the microcontroller 452 convert the signals from the amplifiers 450, 454 to digital and these digital signals are processed by the software of the microcontroller 452. The UV sensor 442 may be, for example, an ultraviolet enhanced photodiode sensitive to light having a wavelength of about 360 nm and the fluorescence sensor 444 may be a blue enhanced photodiode sensitive to light having a wavelength of about 450
20 nm. Such photodiodes are available from, for example, Advanced Photonix, Inc., Massachusetts. The microcontroller 452 may be, for example, a Motorola 68HC16.

The exact characteristics of the sensors 442, 444 and the filters 446, 448 including the wavelength transmittance ranges of the above filters are not as critical to the present invention as the prevention of the fluorescence sensor from generating an
25 output signal in response to ultraviolet light and the ultraviolet sensor from generating an output signal in response to visible light. For example, instead of, or in addition to, filters, a authentication system according to the present invention may employ an ultraviolet sensor which is not responsive to light having a wavelength longer than 400 nm and/or a fluorescence sensor which is not responsive to light having a wavelength
30 shorter than 400 nm.

Calibration potentiometers 458, 460 permit the gains of amplifiers 450, 454 to be adjusted to appropriate levels. Calibration may be performed by positioning a piece

of white fluorescent paper on the transport plate 434 so that it completely covers the rectangular opening 436 of FIG. 2. The potentiometers 458, 460 may then be adjusted so that the output of the amplifiers 450, 454 is 5 volts. Alternatively, calibration may be performed using genuine currency such as a piece of genuine U.S. currency.

- 5 Potentiometers 458 and 460 may be replaced with electronic potentiometers located, for example, within the microcontroller 452. Such electronic potentiometers may permit automatic calibration based on the processing of a single genuine document or a plurality of documents as will be described below.

The implementation of one embodiment of a document authenticating system according to the present invention as illustrated in FIG. 3 with respect to the authentication of U.S. currency will now be described. As discussed above, it has been determined that genuine United States currency reflects a high level of ultraviolet light and does not fluoresce under ultraviolet illumination. It has also been determined that under ultraviolet illumination counterfeit United States currency exhibits one of the

15 four sets of characteristics listed below:

- 1) Reflects a low level of ultraviolet light and fluoresces;
- 2) Reflects a low level of ultraviolet light and does not fluoresce;
- 3) Reflects a high level of ultraviolet light and fluoresces;
- 4) Reflects a high level of ultraviolet light and does not fluoresce.

20 Counterfeit bills in categories (1) and (2) may be detected by a currency authenticator employing an ultraviolet light reflection test according to one embodiment of the present invention. Counterfeit bills in category (3) may be detected by a currency authenticator employing both an ultraviolet reflection test and a fluorescence test according to another embodiment of the present invention. Only counterfeits in

25 category (4) are not detected by the authenticating methods of the present invention.

According to one embodiment of the present invention, fluorescence is determined by any signal that is above the noise floor. Thus, the amplified fluorescent sensor signal 462 will be approximately 0 volts for genuine U.S. currency and will vary between approximately 0 and 5 volts for counterfeit bills depending upon their

30 fluorescent characteristics. Accordingly, an authenticating system according to one embodiment of the present invention will reject bills when signal 462 exceeds approximately 0 volts.

According to one embodiment of the present invention, a high level of reflected UV light ("high UV") is indicated when the amplified UV sensor signal 464 is above a predetermined threshold. The high/low UV threshold is a function of lamp intensity and reflectance. Lamp intensity can degrade by as much as 50% over the life of the lamp and can be further attenuated by dust accumulation on the lamp and the sensors. The problem of dust accumulation is mitigated by enclosing the lamp and sensors in a housing as discussed above. An authenticating system according to one embodiment of the present invention tracks the intensity of the UV light source and readjusts the high/low threshold accordingly. The degradation of the UV light source may be compensated for by periodically feeding a genuine bill into the system, sampling the output of the UV sensor, and adjusting the threshold accordingly. Alternatively, degradation may be compensated for by periodically sampling the output of the UV sensor when no bill is present in the rectangular opening 436 of the transport plate 434. It is noted that a certain amount of UV light is always reflected off the acrylic window 438. By periodically sampling the output of the UV sensor when no bill is present, the system can compensate for light source degradation. Furthermore, such sampling could also be used to indicate to the operator of the system when the ultraviolet light source has burned out or otherwise requires replacement. This may be accomplished, for example, by means of a display reading or an illuminated light emitting diode ("LED"). The amplified ultraviolet sensor signal 464 will initially vary between 1.0 and 5.0 volts depending upon the UV reflectance characteristics of the document being scanned and will slowly drift downward as the light source degrades. In an alternative embodiment to one embodiment wherein the threshold level is adjusted as the light source degrades, the sampling of the UV sensor output may be used to adjust the gain of the amplifier 450 thereby maintaining the output of the amplifier 450 at its initial levels.

It has been found that the voltage ratio between counterfeit and genuine U.S. bills varies from a discernible 2-to-1 ratio to a non-discernible ratio. According to one embodiment of the present invention a 2-to-1 ratio is used to discriminate between genuine and counterfeit bills. For example, if a genuine U.S. bill generates an amplified UV output sensor signal 464 of 4.0 volts, documents generating an amplified UV output sensor signal 464 of 2.0 volts or less will be rejected as counterfeit. As

described above, this threshold of 2.0 volts may either be lowered as the light source degrades or the gain of the amplifier 450 may be adjusted so that 2.0 volts remains an appropriate threshold value.

According to one embodiment of the present invention, the determination of whether the level of UV reflected off a document is high or low is made by sampling the output of the UV sensor at a number of intervals, averaging the readings, and comparing the average level with the predetermined high/low threshold. Alternatively, a comparison may be made by measuring the amount of UV light reflected at a number of locations on the bill and comparing these measurements with those obtained from genuine bills. Alternatively, the output of one or more UV sensors may be processed to generate one or more patterns of reflected UV light and these patterns may be compared to the patterns generated by genuine bills. Such a pattern generation and comparison technique may be performed by modifying an optical pattern technique such as that disclosed in United States Pat. No. 5,295,196 incorporated herein by reference in its entirety or in United States patent application Serial No. 08/287,882 filed August 9, 1994 for a "Method and Apparatus for Document Identification," incorporated herein by reference in its entirety.

In a similar manner, the presence of fluorescence may be performed by sampling the output of the fluorescence sensor at a number of intervals. However, in one embodiment, a bill is rejected as counterfeit U.S. currency if any of the sampled outputs rise above the noise floor. However, the alternative methods discussed above with respect to processing the signal or signals of a UV sensor or sensors may also be employed, especially with respect to currencies of other countries or other types of documents which may employ as security features certain locations or patterns of fluorescent materials.

A currency authenticating system according to the present invention may be provided with means, such as a display, to indicate to the operator the reasons why a document has been rejected, e.g., messages such as "UV FAILURE" or "FLUORESCENCE FAILURE." A currency authenticating system according to the present invention may also permit the operator to selectively choose to activate or deactivate either the UV reflection test or the fluorescence test or both. A currency authenticating system according to the present invention may also be provided with

means for adjusting the sensitivities of the UV reflection and/or fluorescence test, for example, by adjusting the respective thresholds. For example, in the case of U.S. currency, a system according to the present invention may permit the high/low threshold to be adjusted, for example, either in absolute voltage terms or in genuine/suspect ratio terms.

The UV and fluorescence authentication test may be incorporated into various document handlers such as currency counters and/or currency denomination discriminators such as that disclosed in connection with FIG. 1c and U.S. Patent No. 5,295,196 incorporated herein by reference in its entirety. Likewise, the magnetic authentication tests described above may likewise be incorporated in such counters and/or discriminators. In such systems, calibration may be performed by processing a stack of genuine documents. An example of a method of calibrating such a device will now be discussed.

As mentioned above, the acrylic window 438 reflects a certain amount of UV light even when no bill is present. The amount of UV light reflected in the absence of bills is measured. A stack of genuine bills may then be processed with the potentiometer 458 set to some arbitrary value and the resulting UV readings averaged. The difference between the average reading and the reading made in the absence of bills may then be calculated. The potentiometer 458 may then be adjusted so that the average reading would be at least 0.7 volts greater than the no bill reading. It is also desirable to adjust the potentiometer 458 so that the amplifier 450 operates around the middle of its operating range.

For example, if a reading of 1.0 volt results when no bills are present and an average reading of 3.0 volts results when a stack of genuine bills are processed, the resulting difference is 2.0 volts which is greater than 0.7 volts. However, it is desirable for the amplifier to be operating in the range of about 2.0 to 2.5 volts and preferably at about 2.0 volts. Thus in the above example, the potentiometer 458 may be used to adjust the gain of the amplifier 450 so that an average reading of 2.0 volts would result. Where potentiometer 458 is an electronic potentiometer, the gain of the amplifier 450 may be automatically adjusted by the microcontroller 452. In general, when the average reading is too high the potentiometer is adjusted to lower the

resulting values to the center of the operating range of the amplifier and vice versa when the average reading is too low.

According to another embodiment of the present invention, the operator of a document handling device such as a currency counter or a currency denomination discriminator is provided with the ability to adjust the sensitivity of a UV reflection test, a fluorescence test, and a magnetic test. For example, a note counter embodying one embodiment of the present invention may provide the operator the ability to set the authentication tests to a high or a low sensitivity. For example, the note counter may be provided with a set up mode which enables the operator to adjust the sensitivities for each of the above tests for both the high and the low modes. This may be achieved through appropriate messages being displayed on, for example, display 36 of FIG. 1c and the input of selection choices via an input device such as a keyboard or buttons. In one embodiment, the device permits the operator to adjust the UV test, the fluorescent test, and the magnetic test in a range of sensitivities 1 - 7, with 7 being the most sensitive, or to turn each test off. The device permits setting the sensitivity as described above for the three authentication tests for both a low sensitivity (low denomination) mode and a high sensitivity (high denomination) mode. The above setting options are summarized in Table 1.

Table 1

Mode	UV Test Sensitivity	Fluorescent Test Sensitivity	Magnetic Test Sensitivity
High	off, 1-7	off, 1-7	off, 1-7
Low	off, 1-7	off, 1-7	off, 1-7

20

According to an alternate embodiment, the above high/low modes are replaced with denomination modes, for example, one for each of several denominations of currency (e.g., \$1, \$2, \$5, \$10, \$20, \$50 and \$100). For each denomination, the sensitivity of the three tests may be adjusted between 1-7 or off. According to one embodiment for operator manually selects either the high or low mode or the appropriate denomination mode based on the values of the notes to be processed. This manual mode selection system may be employed in, for example, either a note counter

or a currency denomination discriminator. According to another embodiment the document handling system automatically selects either the high or low mode or the appropriate denomination mode based on the values of the notes being processed.

This automatic mode selection system may be employed in systems capable of
 5 identifying the different values or kinds of documents, for example, a currency denomination discriminator.

Accordingly, in the low mode or for low denomination modes (e.g., \$1, \$2) the three tests may be set to relatively low sensitivities (e.g., UV test set at 2, fluorescent test set at 5, and magnetic test set at 3). Conversely, in the high mode or for high
 10 denomination modes (e.g., \$50, \$100) the three tests may be set to relatively high sensitivities (e.g., UV test set at 5, fluorescent test set at 6, and magnetic test set at 7). In this way, authentication sensitivity may be increased when processing high value notes where the potential harm or risk in not detecting a counterfeit may be greater and may be decreased when processing low value notes where the potential harm or risk in
 15 not detecting a counterfeit is lesser and the annoyance of wrongly rejecting genuine notes is greater. Also the UV, fluorescent, and/or magnetic characteristics of genuine notes can vary due to number of factors such wear and tear or whether the note has been washed (e.g., detergents). As a result, the fluorescent detection of genuine U.S. currency, for example, may yield readings of about 0.05 or 0.06 volts.
 20 The UV and fluorescent thresholds associated with each of the seven sensitivity levels may be set, for example, as shown in Table 2.

Table 2

Sensitivity Level	UV Test (Volts)	Fluorescent Test (Volts)
1	0.2	0.7
2	0.3	0.6
3	0.4	0.5
4	0.5	0.3
5	0.55	0.2
6	0.6	0.15
7	0.7	0.1

In performing the UV test according to one embodiment, the no bill reflectance value is subtracted from resulting UV reflectance voltages associated with the scanning of a particular bill, and this difference is compared against the appropriate threshold value such as those in Table 3 in determining whether to reject a bill.

According to one embodiment, the potentiometer 460 associated with the fluorescence detector 444 is calibrated by processing a genuine note or stack of notes, as described above in connection with the calibration of the UV detector, and adjusted so that a reading of near 0 volts (e.g., about 0.1 volt) results. Magnetic calibration may be performed, for example, manually in conjunction with the processing of a genuine bill of known magnetic characteristics and adjusting the magnetic sensor to near the center of its range.

Upon a bill failing one or more of the above tests, an appropriate error message may be displayed such as "Suspect Document U--" for failure of the UV reflection test, "Suspect Document -F-" for failure of the fluorescent test, "Suspect Document --M" for failure of the magnetic test, or some combination thereof when more than one test is failed (e.g., "Suspect Document UF-" for failure of both the UV reflection test and the fluorescent test).

In addition to the above described ultraviolet characteristics, thread-based characteristics may be used to authenticate bills.

New security features are being added to U.S. currency beginning with the 1996 series \$100 bills. Subsequently, similar features will be added to other U.S. denominations such as the \$50 bill, \$20 bill, etc. Some of the new security features include the incorporation into the bills of security threads that fluoresce under

5 ultraviolet light. For example, the security threads in the 1996 series \$100 bills emit a red glow when illuminated by ultraviolet. The color of light illuminated from security threads under ultraviolet light will vary by denomination, for example, with the \$100 notes emitting red light and the \$50 notes emitting, for example, blue light or purple light.

10 Additionally, the location of the thread within the bill can be used as a security feature. For example, the security threads in all \$100 bills are located in the same position. Furthermore, the location of the security threads in other denominations will be the same by denomination and will vary among several denominations. For example, the location of security threads in \$10s, \$20s, \$50, and \$100 may all be
15 distinct. Alternatively, the location may be the same in the \$20s and the \$100s but different from the location of the security threads in the \$50s.

The ultraviolet system described above in connection with FIGs. 2 and 3 may be modified to take advantage of this feature. Referring to FIG. 4, a bill 330 is shown indicating three possible locations 332a - 332c for security threads in genuine bills
20 depending on the denomination of the bill. Fluorescent light detectors 334a - 334c are positioned over the possible acceptable locations of fluorescing security threads. In systems designed to accept bills fed in either the forward or the reverse direction, identical detectors are positioned over the same locations on each half of the bill. For example, sensors 334c are positioned a distance d_5 to the left and right of the center of
25 the bill 330. Likewise, sensors 334b are positioned a distance d_6 to the left and right of the center of the bill 330 while sensors 334a are positioned a distance d_7 to the left and right of the center of the bill 330. Additional sensors may be added to cover additional possible thread locations.

These sensors may be designed to detect a particular color of light depending
30 on their location. For example, say location 332b corresponds to the location of security threads in genuine \$100 bills and location 332c corresponds to the location of security threads in genuine \$50 bills. Furthermore, if the security threads in \$100 bills

emit red light under ultraviolet light excitation and the security threads in \$50 bills emit blue light under ultraviolet light excitation, then sensor 334b may be particularly designed to detect red light and sensor 334c may be designed to detect blue light. Such sensors may employ filters which pass red and blue light, respectfully, while
 5 screening out light of other frequencies. Accordingly, for example, sensor 334b will respond to a security thread located at location 332b that emits red light under ultraviolet light excitation but not to a security thread at location 332b that emits blue light.

In another embodiment, one or more sensors located at a given lateral position
 10 may detect light of a plurality of wavelengths. For example, suppose the location of security threads for both the \$100 and the \$20 bills is at location 332b and suppose threads in genuine \$100 bills emit red light under ultraviolet excitation while threads in genuine \$20 bills emit green light. One or more sensors located over location 332b such as sensor 334b are then used to detect both the presence of threads at location
 15 332b and the emitted color. Accordingly, the denomination and/or genuineness of a bill can be determined and/or authenticated.

Likewise, one or more sensors located at a plurality of lateral position may detect light of the same or different wavelengths. For example, suppose the location of security threads for \$100 bills is at location 332b and the location of security threads
 20 for \$10 bills is at location 332a and suppose threads in both genuine \$100 bills and genuine \$10 bills emit red light under ultraviolet excitation. One or more sensors located over location 332b such as sensor 334b and one or more sensors located over location 332a such as sensor 334a are then used to detect both the presence of threads at locations 332b and 332a and the emitted color. In one embodiment the sensors may
 25 be designed to detect only red light. Alternatively, the sensors may be designed to detect a plurality of colors of light and provide an indication of the color that is detected. Accordingly, the denomination and/or genuineness of a bill can be determined and/or authenticated.

Sensors 334a - 334c may include separate sources of ultraviolet light or one or
 30 more separate ultraviolet light sources may be provided to illuminate the bill or portions of the bill, either on the same side of the bill as the sensors or on the opposite side of the bill. These sensors may be arranged along the same axis or, alternatively,

may be staggered upstream and downstream relative to each other. These sensors may be arranged all on the same side of the bill or some on one side of the bill and some on the other. Alternatively, for one or more locations 332a - 332c sensors may be placed on both sides of the bill. This dual sided embodiment would be beneficial in detecting counterfeits made by applying an appropriate fluorescing material on the surface of a bill. Alternatively, a combination of normal lighting and ultraviolet lighting may be employed but at different times to detect for the presence of a colored line applied to the surface of a bill visible in normal lighting. According to such an embodiment, no colored thread should be detected under normal lighting and an appropriate colored thread in an appropriate position must be detected under ultraviolet lighting.

Additionally, the authentication technique described above in connection with FIGs. 2 and 3 may be employed in areas where no fluorescing security threads might be located, for example, near the center of the bill, such that the detection of fluorescent light would indicate a counterfeit bill as would the absence of a high level of reflected ultraviolet light.

Alternatively or additionally, sensors may be employed to detect bills or security threads printed or coated with thermochromatic materials (materials that change color with a change in temperature). Examples of threads incorporating thermochromatic materials are described in U.S. Pat. No. 5,465,301 incorporated herein by reference. For example, a security thread may appear in one color at ambient temperatures under transmitted light and may appear in a second color or appear colorless at or above an activation temperature or vice versa. Alternatively, bills may be printed and/or coated with such thermochromatic materials. Such bills may or may not include security threads and any included security threads may or may not also be printed or coated with thermochromatic materials. To detect for the proper characteristics of bills containing such thermochromatic materials and/or containing threads employing such thermochromatic materials, the above described embodiments may be altered to scan a bill at different temperatures. For example, a bill could first be scanned at ambient temperatures, and then be transported downstream where the temperature of the bill is raised to or above an activation temperature and scanned again at the higher temperature. For example, FIG. 4 could be modified to employ two sets of pairs of sensors 334a-c, one set downstream of the other with the

210

downstream sensors be located in a region where the temperature is evaluated relative to the temperature of the region where the first set of sensors are located. A bill adjacent to the first and second sets of sensors 334a-c may be illuminated either with visible light or ultraviolet light (if the thermochromatic material contains materials whose fluorescent characteristics alter with changes in temperature). Accordingly, the presence of the appropriate color or absence of color may be detected for the different temperatures and the detected information may be used to authenticate and/or denominate the bill.

In addition to magnetic and optical sensing, other techniques of detecting characteristic information of currency include electrical conductivity sensing, capacitive sensing (U.S. Pat. No. 5,122,754 [watermark, security thread]; 3,764,899 [thickness]; 3,815,021 [dielectric properties]; 5,151,607 [security thread]), and mechanical sensing (U.S. Pat. No. 4,381,447 [limpness]; 4,255,651 [thickness]).

Turning to the discrimination of the denomination of bills, in the case of U.S. currency, for instance, it has been determined that the central, approximately two-inch (approximately 5 cm) portion of currency bills, as scanned across the central section of the narrow dimension of the bill, provides sufficient data for distinguishing among the various U.S. currency denominations. According to one embodiment, an optical encoder (see e.g. FIGS. 1a-c) can be used to control the scanning process so that reflectance samples are taken for a set period of time and only after a certain period of time has elapsed after the borderline 17a is detected, thereby restricting the scanning to the desired central portion of the narrow dimension of the bill.

FIGs. 5-7 illustrate the scanning process in more detail. Referring to FIG. 6, as a bill 17 is advanced in a direction parallel to the narrow edges of the bill, scanning via a slit in the scanhead 18a or 18b is effected along a segment S of the central portion of the bill 17. This segment S begins a fixed distance D inboard of the borderline 17a. As the bill 17 traverses the scanhead, a strip s of the segment S is always illuminated, and the photodetector 26 produces a continuous output signal which is proportional to the intensity of the light reflected from the illuminated strip s at any given instant. This output is sampled at intervals controlled by the encoder, so that the sampling intervals are precisely synchronized with the movement of the bill across the scanhead.

As illustrated in FIGs. 5 and 7, the sampling intervals in one embodiment are selected so that the strips s that are illuminated for successive samples overlap one another. The odd-numbered and even-numbered sample strips have been separated in FIGs. 5 and 7 to more clearly illustrate this overlap. For example, the first and second strips s_1 and s_2 overlap each other, the second and third strips s_2 and s_3 overlap each other, and so on. Each adjacent pair of strips overlap each other. In the illustrative example, this is accomplished by sampling strips that are 0.050 inch (0.127 cm) wide at 0.029 inch (0.074 cm) intervals, along a segment S that is 1.83 inch (4.65 cm) long (64 samples).

FIGs. 8a and 8b illustrate two opposing surfaces of U.S. bills. The printed pattern on the black and green surfaces of the bill are each enclosed by respective thin borderlines B_1 and B_2 . As a bill is advanced in a direction parallel to the narrow edges of the bill, scanning via the wide slit of one of the scanheads is effected along a segment S_A of the central portion of the black surface of the bill (FIG. 8a). As previously stated, the orientation of the bill along the transport path determines whether the upper or lower scanhead scans the black surface of the bill. This segment S_A begins a fixed distance D_1 inboard of the borderline B_1 , which is located a distance W_1 from the edge of the bill. The scanning along segment S_A is as describe in connection with FIGs. 5-7.

Similarly, the other of the two scanheads scans a segment S_B of the central portion of the green surface of the bill (FIG. 8b). The orientation of the bill along the transport path determines whether the upper or lower scanhead scans the green surface of the bill. This segment S_B begins a fixed distance D_2 inboard of the border line B_2 , which is located a distance W_2 from the edge of the bill. For U.S. currency, the distance W_2 on the green surface is greater than the distance W_1 on the black surface. It is this feature of U.S. currency which permits one to determine the orientation of the bill relative to the upper and lower scanheads 18, thereby permitting one to select only the data samples corresponding to the green surface for correlation to the master characteristic patterns. The scanning along segment S_B is as describe in connection with FIGs. 5-7.

The optical sensing and correlation technique is based upon using the above process to generate a series of stored intensity signal patterns using genuine bills for

each denomination of currency that is to be detected. According to one embodiment, two or four sets of master intensity signal samples are generated and stored within the system memory, preferably in the form of an EPROM 34 (see FIG. 1a), for each detectable currency denomination. According to one embodiment these are sets of master green-surface intensity signal samples. In the case of U.S. currency, the sets of master intensity signal samples for each bill are generated from optical scans, performed on the green surface of the bill and taken along both the "forward" and "reverse" directions relative to the pattern printed on the bill. Alternatively, the optical scanning may be performed on the black side of U.S. currency bills or on either surface of foreign bills. Additionally, the optical scanning may be performed on both sides of a bill.

In adapting this technique to U.S. currency, for example, sets of stored intensity signal samples are generated and stored for seven different denominations of U.S. currency, i.e., \$1, \$2, \$5, \$10, \$20, \$50 and \$100. For bills which produce significant pattern changes when shifted slightly to the left or right, such as the \$2, the \$10 and/or the \$100 bills in U.S. currency, two green-side patterns for each of the "forward" and "reverse" directions may be stored, each pair of patterns for the same direction represent two scan areas that are slightly displaced from each other along the long dimension of the bill. Accordingly, a set of number of different green-side master characteristic patterns are stored within the EPROM for subsequent correlation purposes. The generation of the master patterns is discussed in more detail in United States Patent No. 5,295,196 which is incorporated herein by reference in its entirety. Once the master patterns have been stored, the pattern generated by scanning a bill under test is compared by the CPU 30 with each of the master patterns of stored intensity signal samples to generate, for each comparison, a correlation number representing the extent of correlation, i.e., similarity between corresponding ones of the plurality of data samples, for the sets of data being compared.

The CPU 30 is programmed to identify the denomination of the scanned bill as corresponding to the set of stored intensity signal samples for which the correlation number resulting from pattern comparison is found to be the highest. In order to preclude the possibility of mischaracterizing the denomination of a scanned bill, as well as to reduce the possibility of spurious notes being identified as belonging to a valid

denomination, a bi-level threshold of correlation is used as the basis for making a "positive" call. If a "positive" call can not be made for a scanned bill, an error signal is generated. See, e.g., United States Patent No. 5,295,196.

According to one embodiment, master patterns are also stored for selected
 5 denominations corresponding to scans along the black side of U.S. bills. More particularly, according to one embodiment, multiple black-side master patterns are stored for \$20, \$50 and \$100 bills. For each of these denominations, three master patterns are stored for scans in the forward and reverse directions for a total of six patterns for each denomination. For a given scan direction, black-side master patterns
 10 are generated by scanning a corresponding denominated bill along a segment located about the center of the narrow dimension of the bill, a segment slightly displaced (0.2 inches) to the left of center, and a segment slightly displaced (0.2 inches) to the right of center. When the scanned pattern generated from the green side of a test bill fails to sufficiently correlate with one of the green-side master patterns, the scanned pattern
 15 generated from the black side of a test bill is then compared to black-side master patterns in some situations.

Using the above sensing and correlation approach, the CPU 30 is programmed to count the number of bills belonging to a particular currency denomination as part of a given set of bills that have been scanned for a given scan batch, and to determine the
 20 aggregate total of the currency amount represented by the bills scanned during a scan batch. The CPU 30 is also linked to an output unit 36 (FIGs. 1a-c) which is adapted to provide a display of the number of bills counted, the breakdown of the bills in terms of currency denomination, and the aggregate total of the currency value represented by counted bills. The display 36 can also be adapted to provide a print-out of the
 25 displayed information in a desired format.

Referring again to the embodiment depicted in FIG. 1c, as a result of the first comparison described above based on the reflected light intensity information retrieved by scanhead 18, the CPU 30 will have either determined the denomination of the scanned bill 17 or determined that the first scanned signal samples fail to sufficiently
 30 correlate with any of the sets of stored intensity signal samples in which case an error is generated. Provided that an error has not been generated as a result of this first comparison based on reflected light intensity characteristics, a second comparison is

performed. This second comparison is performed based on a second type of characteristic information, such as alternate reflected light properties, similar reflected light properties at alternate locations of a bill, light transmissivity properties, various magnetic properties of a bill, the presence of a security thread embedded within a bill, the color of a bill, the thickness or other dimension of a bill, etc. The second type of characteristic information is retrieved from a scanned bill by the second scanhead 39. The scanning and processing by scanhead 39 may be controlled in a manner similar to that described above with regard to scanhead 18.

In addition to the sets of stored first characteristic information, in this example stored intensity signal samples, the EPROM 34 stores sets of stored second characteristic information for genuine bills of the different denominations which the device 10 is capable of handling. Based on the denomination indicated by the first comparison, the CPU 30 retrieves the set or sets of stored second characteristic data for a genuine bill of the denomination so indicated and compares the retrieved information with the scanned second characteristic information. If sufficient correlation exists between the retrieved information and the scanned information, the CPU 30 verifies the genuineness of the scanned bill 17. Otherwise, the CPU generates an error. While the embodiment illustrated in FIG. 1c depicts a single CPU 30 for making comparisons of first and second characteristic information and a single EPROM 34 for storing first and second characteristic information, it is understood that two or more CPUs and/or EPROMs could be used, including one CPU for making first characteristic information comparisons and a second CPU for making second characteristic information comparisons. Using the above sensing and correlation approach, the CPU 30 is programmed to count the number of bills belonging to a particular currency denomination whose genuineness has been verified as part of a given set of bills that have been scanned for a given scan batch, and to determine the aggregate total of the currency amount represented by the bills scanned during a scan batch.

FIG. 9 depicts an exterior perspective view and FIG. 10 is a side view of a multi-pocket document evaluation device 10 such as a currency evaluator according to one embodiment of the present invention. According to one embodiment the evaluation device 10 is compact having a height (H) of about 17 ½ inches, width (W)

of about 13 ½ inches, and a depth (D) of about 15 inches. The evaluation device 10 may be rested upon a tabletop.

In FIGs. 9 and 10, currency bills are fed, one by one, from a stack of currency bills placed in an input receptacle 12 into a transport mechanism. The transport mechanism includes a transport plate or guide plate 240 for guiding currency bills to one of a plurality of output receptacles 217a and 217b. Before reaching the output receptacles 217a, 217b a bill can be, for example, evaluated, analyzed, authenticated, discriminated, counted and/or otherwise processed. The results of the above process or processes may be used to determine to which output receptacle 217a, 217b a bill is directed. In one embodiment, documents such as currency bills are transported, scanned, and identified at a rate in excess of 800 bills per minute. In another embodiment, documents such as currency bills are transported, scanned, and identified at a rate in excess of 1000 bills per minute. In of currency bills, the identification includes the determine of the denomination of each bill.

The input receptacle 12 for receiving a stack of bills to be processed is formed by downwardly sloping and converging walls 205 and 206 (see FIG. 10) formed by a pair of removable covers (not shown) which snap onto a frame. The converging wall 206 supports a removable hopper (not shown) that includes vertically disposed side walls (not shown). One embodiment of an input receptacle is described and illustrated in more detail in United States patent application Serial No. 08/450,505 filed May 26, 1995, entitled "Method and Apparatus for Discriminating and Counting Documents" which is incorporated by reference in its entirety. The evaluation device 10 in FIG. 9 has a touch panel display 15 in one embodiment of the present invention which displays appropriate "functional" keys when appropriate. The touch panel display 15 simplifies the operation of the multi-pocket currency discriminator 10. Alternatively or additionally physical keys or buttons may be employed.

From the input receptacle 12, the currency bills are moved in seriatim from a bottom of the stack along a curved guideway 211 (shown in FIG. 9) which receives bills moving downwardly and rearwardly and changes the direction of travel to a forward direction. A stripping wheel mounted on a stripping wheel shaft 219 aids in feeding the bills to the curved guideway 211. The curvature of the guideway 211 corresponds substantially to the curved periphery of a drive roll 223 so as to form a

narrow passageway for the bills along the rear side of the drive roll 223. An exit end of the curved guideway 211 directs the bills onto the transport plate 240 which carries the bills through an evaluation section and to one of the output receptacles 217a, 217b.

Stacking of the bills in one embodiment is accomplished by a pair of driven
 5 stacking wheels 212a and 213a for the first or upper output receptacle 217a and by a pair of stacking wheels 212b and 213b for the second or bottom output receptacle 217b. The stacker wheels 212a,b and 213a,b are supported for rotational movement about respective shafts 215a,b journaled on a rigid frame and driven by a motor (not shown). Flexible blades of the stacker wheels 212a and 213a deliver the bills onto a
 10 forward end of a stacker plate 214a. Similarly, the flexible blades of the stacker wheels 212b and 213b deliver the bills onto a forward end of a stacker plate 214b.

A diverter 260 directs the bills to either the first or second output receptacle 217a, 217b. When the diverter is in a lower position, bills are directed to the first output receptacle 217a. When the diverter 260 is in an upper position, bills proceed in
 15 the direction of the second output receptacle 217b.

Referring to FIG. 11, at a lower end of the curved guideway 211, a bill 20 being transported by the drive roll 223 engages the transport plate 240. Bills are positively driven along the transport plate 240 by means of a transport roll arrangement comprising both driven and passive rolls. A pair of O-rings 244 and 245
 20 fit into grooves formed in a drive roll 241 and in the drive roll 223. The pair of O-rings 244 and 245 engage the bill 20 continuously between the two driven upper rolls 223 and 241 and assist in holding the bill 20 flat against the transport plate 240. Such an embodiment aids to the performance of the sensors of the evaluation region 247. Rolls 223 and 241 are driven by a motor (not shown) via a belt 21. Such an
 25 arrangement is illustrated in more detail in United States patent application Serial No. 08/450,505 referred to above.

Passive rolls 250, 251 are mounted on an underside of the transport plate 240 in such a manner as to be freewheeling about their respective axes 254 and 255 and biased into counter-rotating contact with their corresponding driven upper rolls 223
 30 and 241. The passive rolls 250 and 251 preferably have high-friction rubber surfaces and are biased into contact with their respective driven upper rolls 223 and 241 by means of a pair of H-shaped leaf springs 252 and 253 (see FIG. 12). The central

portion of each leaf spring is fastened to the transport plate 240, which is fastened rigidly to the machine frame, so that the relatively stiff arms of the H-shaped springs exert a constant biasing pressure against the passive rolls 250 and 251 and push them against the corresponding upper rolls 223 and 241.

5 The location of a magnetic head 256 and a magnetic head adjustment screw 257 are illustrated in FIG. 12. The adjustment screw 257 adjusts the proximity of the magnetic head 256 relative to a passing bill and thereby adjusts the strength of the magnetic field in the vicinity of the bill.

Referring back to FIG. 11, the driven and passive transport rolls are preferably
10 coplanar with a flat upper surface of the transport plate 240 so that currency bills can be positively driven along the top surface of the plate in a flat manner. To minimize the possibility of bill skew and to enhance the reliability of the overall scanning and recognition process, the bills are firmly gripped under uniform pressure between the driven and passive rolls. The H-shaped leaf springs 252 and 253 aid in reducing bill
15 twisting or skewing. The O-rings 244, 245 are also effective in ensuring that central portions of the bills are held flat. The distance between the axes of the two driven upper rolls 223 and 241 and the corresponding counter-rotating passive rolls 250 and 251 is selected to be just short of a length of a narrow dimension of the currency bills.

FIG. 13 depicts various shafts of the multi-pocket document evaluation device
20 10 according to one embodiment of the present invention. The distance between the shafts should preferably be less than the width of the bills that are to be evaluated. As shown in FIG. 13, the optical encoder 32 is mounted on the shaft of the roller 241 for precisely tracking the position of each bill as it is transported through the machine, as discussed in detail above in connection with the optical sensing and correlation
25 technique.

FIGs. 14 and 15 illustrate respectively, first and second follower plates 262 and 278. As illustrated, these plates are substantially free from surface features and are substantially smooth like the transport plate 240. The follower plates 262 and 278 are positioned in spaced relation to transport plate 240 so as to define a currency pathway
30 therebetween. The follower plates 262 and 278 and the transport plate 240 contribute to defining a pathway that is free and unencumbered pathway between the roll 251 and the output receptacles 217a and 217b for the bill. As illustrated, the follower plates

262 and 278 have apertures only where necessary for accommodation of passive rolls 268, 270, 284, and 286. Thus according to one embodiment a transport mechanism is employed that uses no belts to advance bills from the evaluation region to one of a plurality of output receptacles.

5 Referring specifically to FIG. 14, the follower plate 262 in conjunction with the upper portion of the transport plate 240 guide a bill 20 from the passive roll 251 to a driven roll 264 and then to a driven roll 266. The passive rolls 268, 270 are biased by H-spring 272 and 273 into counter-rotating contact with the corresponding driven rolls 264 and 266 in a manner similar as described above in connection with passive rolls
10 250 and 251.

A diverter 260 is employed to direct the bill 20 to the appropriate output receptacle 217a or 217b. The bill 20 will encounter the diverter 260 after emerging from between the driven roll 266 and the passive roll 270. Diverter 260 includes a plurality of flanges mounted across the transport path on a shaft 274. Two solenoids
15 261a,b, one mounted on each end of the shaft 274 (see FIG. 13), cause the shaft and the attached diverter flanges to rotate into either a lower position or an upper position. The two solenoids drive the shaft 274 in opposite directions and an appropriate one of the two solenoids is energized depending upon whether the diverter 260 is to be moved from its lower position to its upper position or vice versa. The use of a
20 separate solenoid for each rotational direction enhances the performance of the diverter 260 by increasing of the speed in which the position of the diverter 260 may be changed.

When the diverter 260 is in the upper position (as shown in FIG. 14), bills are directed between the transport plate 240 and the follower plate 278 (see FIG. 15). The
25 transport plate 240 and the follower plate 278 guide bills after the diverter 260 to a driven roll 280 and then to a driven roll 282.

FIG. 15 illustrates a bill 20 between the driven rolls 280 and 282 and their respective passive rolls 284 and 286. The passive rolls 284, 286 are biased by H-springs 288, 289 into passive counter-rotating contact with the driven rolls 280, 282,
30 respectively, in a manner similar to that described above in connection with passive rolls 250, 251. Bills are then directed to the lower output receptacle 217b via the stacker wheels 212b and 213b.

FIGs. 16a-c depict multi-pocket document evaluation devices 10, such as a currency evaluators, according to embodiments of the present invention. FIG. 16a depicts a three-pocket document evaluation device 10, such as a currency evaluator. FIG. 16b depicts a four-pocket document evaluation device 10, such as a currency evaluator. FIG. 16c depicts a six-pocket document evaluation device 10, such as a currency evaluator.

The multi-pocket document evaluation devices 10 in FIGs. 16a-c have a transport mechanism which includes a transport plate or guide plate 240 for guiding currency bills to one of a plurality of output receptacles 217. The transport plate 240 according to one embodiment is substantially flat and linear without any protruding features. Before reaching the output receptacles 217, a bill can be, for example, evaluated, analyzed, authenticated, discriminated, counted and/or otherwise processed.

The multi-pocket document evaluation devices 10 move the currency bills in seriatim from a bottom of the stack along the curved guideway 211 which receives bills moving downwardly and rearwardly and changes the direction of travel to a forward direction. An exit end of the curved guideway 211 directs the bills onto the transport plate 240 which carries the bills through an evaluation section and to one of the output receptacles 217. A plurality of diverters 260 direct the bills to the output receptacles 217. When the diverter 260 is in a lower position, bills are directed to the corresponding output receptacle 217. When the diverter 260 is in an upper position, bills proceed in the direction of the remaining output receptacles.

The multi-pocket document evaluation devices 10 of FIG. 16a-c according to one embodiment includes passive rolls 250, 251 which are mounted on an underside of the transport plate 240 and are biased into counter-rotating contact with their corresponding driven upper rolls 223 and 241. Other embodiments includes a plurality of follower plates which are substantially free from surface features and are substantially smooth like the transport plate 240. The follower plates 262 and 278 are positioned in spaced relation to transport plate 240 so as to define a currency pathway therebetween. In one embodiment, follower plates 262 and 278 have apertures only where necessary for accommodation of passive rolls 268, 270, 284, and 286.

The follower plate, such as follower plate 262, work in conjunction with the upper portion of the transport plate 240 to guide a bill 20 from the passive roll 251 to

a driven roll 264 and then to a driven roll 266. The passive rolls 268, 270 are biased by H-springs into counter-rotating contact with the corresponding driven rolls 264 and 266.

Turning now to FIG. 17a, there is shown a functional block diagram illustrating an embodiment of a document authenticator and discriminator according to the present invention. The discriminator system 302 comprises an input receptacle 304 for receiving a stack of currency bills. A transport mechanism defining a transport path (as represented by arrow M) transports the bills in the input receptacle, one at a time, past one or more sensors of an authenticating and discriminating unit 306. Bills are then transported to one of a plurality of output receptacles 308 (arrow N). The system 302 may correspond, for example, to the discriminators described above having multiple output pockets such as those shown in FIGs. 9, 10, and 16a-16c. The authenticating and discriminating unit scans and determines the denomination of each passing bill. Any variety of discriminating techniques may be used. For example, the discriminating method disclosed in U.S. Pat. No. 5,295,196 (incorporated herein in its entirety) may be employed to optically scan each bill. Depending on the characteristics of the discriminating unit employed, the discriminator may be able to recognize bills only if fed face up or face down, regardless of whether fed face up or face down, only if fed in a forward orientation or reverse orientation, regardless of whether fed in a forward or reverse orientation, or some combination thereof. Additionally, the discriminating unit may be able to scan only one side or both sides of a bill. In addition to determining the denomination of each scanned bill, the authenticating and discriminating unit 306 may additionally include various authenticating tests such as an ultraviolet authentication test as disclosed in U.S. patent application Serial No. 08/317,349 filed on October 4, 1994 for a "Method and Apparatus for Authenticating Documents Including Currency" incorporated herein by reference in its entirety. Likewise, the authenticating and discriminating unit 306 may additionally include other authentication tests such as thread detection, enhanced magnetics tests, and color authentication tests including those described in co-pending U.S. patent application Serial No. ~~XXXXXX,XXX~~ ^{08/800,053} filed on February 14, 1997 entitled "Method and Apparatus for Document Identification and Authentication" incorporated herein by reference in its entirety.

Signals from the authenticating and discriminating unit 306 are sent to a signal processor such as a central processor unit ("CPU"). The CPU records the results of the authenticating and discriminating tests in a memory. When the authenticating and discriminating unit 306 is able to confirm the genuineness and denomination of a bill, the value of the bill is added to a total value counter in memory that keeps track of the total value of the stack of bills that were inserted in the input receptacle 304 and scanned by the authenticating and discriminating unit 306. Additionally, depending on the mode of operation of the discriminator system 302, counters associated with one or more denominations may be maintained in the memory. For example, a \$1 counter may be maintained to record how many \$1 bills were scanned by the authenticating and discriminating unit 306. Likewise, a \$5 counter may be maintained to record how many \$5 bills were scanned, and so on. In an operating mode where individual denomination counters are maintained, the total value of the scanned bills may be determined without maintaining a separate total value counter. The total value of the scanned bills and/or the number of each individual denomination may be displayed on a display such as a monitor or LCD display.

A discriminating unit such as the authenticating and discriminating unit 306 may not be able to identify the denomination of one or more bills in the stack of bills loaded into the input receptacle 304. For example, if a bill is excessively worn or soiled or if the bill is torn a discriminating unit may not be able to identify the bill. Furthermore, some known discrimination methods do not have a high discrimination efficiency and thus are unable to identify bills which vary even somewhat from an "ideal" bill condition or which are even somewhat displaced by the transport mechanism relative to the scanning mechanism used to discriminate bills. Accordingly, such poorer performing discriminating units may yield a relatively large number of bills which are not identified. Alternatively, some discriminating units may be capable of identifying bills only when they are fed in a predetermined manner. For example, some discriminators may require a bill to be faced in a predetermined manner. Accordingly, when a bill is fed face down past a discriminating unit which can only identify bills fed face up, the discriminating unit can not identify the bill. Likewise, other discriminators require a specific edge of a bill to be fed first, for example, the top edge of a bill.

Accordingly, bills which are not fed in the forward direction, that is, those that are fed in the reverse direction, are not identified by such a discriminating unit.

According to one embodiment, the discriminator system 302 is designed so that when the authenticating and discriminating unit is unable to identify a bill, the
 5 unidentified note is "presented" in one of the output receptacles, that is, the transport mechanism is stopped so that the unidentified bill is located at a predetermined position within one of the output receptacles, such as being the last bill transported to one of the output receptacles. For example, where the unidentified bill is the last bill transported to an output receptacle, it may be positioned within the stacker wheels or
 10 positioned at the top of or at the rear of the stack of bills resting on a stacker plate in the output receptacle 308. The output receptacles 308 are preferably positioned within the discriminator system 302 so that the operator may conveniently see the flagged bill and/or remove it for closer inspection. Accordingly, the operator is able to easily see the bill which has not been identified by the authenticating and discriminating unit 306.
 15 The operator may then either visually inspect the flagged bill while it is resting on the top of or at the rear of the stack, or alternatively, the operator may chose to remove the bill from the output receptacle in order to examine the flagged bill more closely.

According to another embodiment, when a bill is flagged, the transport mechanism may be stopped before the flagged bill is transported to one of the output
 20 receptacles. Such an embodiment is particularly suited for situations in which the operator need not examine the bill being flagged, such as upon the occurrence of a denomination change or separate series error described below. For example, upon the occurrence of a denomination change where all available output receptacles already have one or more bills in them, the machine may stop with the denomination change
 25 bill residing within the transport mechanism. The machine may then prompt the operator to remove all the bills from a given output receptacle. When the operator does so, the machine automatically resumes operation (or alternatively, the machine may resume operation after the selection of a continue key) and delivers the denomination change bill into the cleared output receptacles.

30 The discriminator system 302 may be designed to continue operation automatically when a flagged bill is removed from the output receptacle or, according to one embodiment of the present invention, may be designed to require a selection

element to be depressed. Upon examination of a flagged bill by the operator, it may be found that the flagged bill is genuine even though it was not identified by the discriminating unit. However, because the bill was not identified, the total value and/or denomination counters in the memory will not reflect its value. According to one embodiment, such an unidentified bill is removed from the output stack and either re-fed through the discriminator or set aside. In the latter case, any genuine set aside bills are counted by hand.

In order to avoid problems associated with re-feeding bills, counting bills by hand, and adding together separate totals, according to one embodiment of the present invention, a number of selection elements associated with individual denominations are provided. These selection elements may be in the form of keys or buttons of a keypad. Other types of selection elements such as switches or displayed keys in a touch-screen environment may be employed. When an operator determines that a flagged bill is acceptable, the operator may simply depress the selection element associated with the denomination of the flagged bill and the corresponding denomination counter and/or the total value counter are appropriately incremented and the discriminator system 302 resumes operating again. In non-automatic restart discriminators, where an operator has removed a genuine flagged bill from the output receptacle for closer examination, the bill is first replaced into the output receptacle before a corresponding selection element is chosen.

An advantage of the above described procedure is that appropriate counters are incremented and the discriminator is restarted with the touch of a single key, greatly simplifying the operation of the discriminator system 302 while reducing the opportunities for human error. When an operator determines that a flagged bill is not acceptable, the operator may remove the unacceptable flagged bill from the output receptacle without replacement and depress a continuation key on the keypad. When the continuation key is selected, the denomination counters and the total value counter are not affected and the discriminator system 302 will resume operating again. In automatic restart discriminators, the removal of a bill from the output receptacle is treated as an indication that the bill is unacceptable and the discriminator automatically resumes operation without affecting the denomination counters and/or total value counters.

Turning now to FIG. 17b, there is shown a functional block diagram illustrating a two-pocket document authenticator and discriminator according to one embodiment of the present invention. The discriminator system 303 comprises an input receptacle 304' for receiving a stack of currency bills. A transport mechanism defining a transport path (as represented by arrow M') transports the bills in the input receptacle, one at a time, past one or more sensors of an authenticating and discriminating unit 306'. Bills are then transported to one of two output receptacles 308', 308'' (as represented by arrows N', N'').

In one embodiment, where the authenticating and discriminating unit 306' determines that a bill is a fake, the flagged bill is routed to a specific one of the output receptacles. The operation of the discriminator may or may not then be suspended. When a bill is not determined to be fake but for some reason the authenticating and discriminating unit 306' is not able to identify the denomination of the bill, the no call bill may be transported to one of the output receptacles 308', 308''. In one embodiment, no call bills are transported to a specific one of the output receptacles 308', 308''. In another embodiment, no call bills are not delivered to a special separate output receptacle. The operation of the discriminator may or may not then be suspended. For example, in a two output pocket discriminator, all bills may be transported to the same output receptacle regardless of whether they are determined to be suspect, no call, or properly identified. In this example, the operation of the discriminator may be suspended and an appropriate message displayed when a suspect or no call bill is encountered. Alternatively, suspect bills may be delivered to a specific one of the two output receptacles (*i.e.*, a reject receptacle) and no calls and identified bills may be sent to the other output receptacle. In this example, the operation of the discriminator need not be suspended when a suspect bill is encountered but may be suspended when a no call bill is encountered. If the operation is suspended at the time the no call bill is detected and the operator determines that the no call bill is acceptable, the operator returns the bill to the output receptacle from which it was removed (if it was removed) and selects a selection element (not shown) corresponding to the denomination of the flagged bill. Appropriate counters (not shown) are incremented, the discriminator system 303 resumes operation. On the other hand, if the operator determines that the flagged bill is unacceptable, the operator removes the bill without

replacement from the output receptacle and selects a continuation element (not shown). The discriminator system 303 resumes operation without incrementing the counters associated with the various denomination and/or the total value counters.

In another embodiment, no call bills are delivered to a specific output
 5 receptacle separate from the output receptacle receiving identified bills. The operation of the discriminator need not be suspended until all the bills placed in the input receptacle 304 have been processed. Alternatively, the operation of the discriminator need not be suspended when a no call is encountered but may be suspended when a suspect bill is detected so that the operator may remove any suspect bills from the
 10 discriminator. The value of any no call bills may then be added to the appropriate counters after the stack of bills has been processed through a reconciliation process.

In an alternate embodiment, suspect and no call bills may be delivered to a specific one of the two output receptacles (*i.e.*, a reject receptacle) and identified bills may be sent to the other output receptacle. Additionally, according to this
 15 embodiment, the operation of the discriminator may be suspended and an appropriate message displayed when a suspect or no call bill is encountered.

The upper and lower scanhead assemblies are shown most clearly in FIGs. 18-21. It can be seen that the housing for each scanhead is formed as an integral part of a unitary molded plastic support member 280 or 281 that also forms the housings for the
 20 light sources and photodetectors of the photosensors PS1 and PS2. The lower member 281 also forms the flat guide plate 240 that receives the bills from the drive roll 223 and supports the bills as they are driven past the scanheads 18a and 18b.

The two support members 280 and 281 are mounted facing each other so that the lenses 282 and 283 of the two scanheads 18a, 18b define a narrow gap through
 25 which each bill is transported. Similar, but slightly larger, gaps are formed by the opposed lenses of the light sources and photodetectors of the photosensors PS1 and PS2. The upper support member 280 includes a tapered entry guide 280a which guides an incoming bill into the gaps between the various pairs of opposed lenses.

The lower support member 281 is attached rigidly to the machine frame. The
 30 upper support member 280, however, is mounted for limited vertical movement when it is lifted manually by a handle 284, to facilitate the clearing of any paper jams that occur beneath the member 280. To allow for such vertical movement, the member 280

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is slidably mounted on a pair of posts 285 and 286 on the machine frame, with a pair of springs 287 and 288 biasing the member 280 to its lowermost position.

Each of the two optical scanheads 18a and 18b housed in the support members 280, 281 includes a pair of light sources acting in combination to uniformly illuminate light strips of the desired dimension on opposite sides of a bill as it is transported across the plate 240. Thus, the upper scanhead 18a includes a pair of LEDs 22a, directing light downwardly through an optical mask on top of the lens 282 onto a bill traversing the flat guide plate 240 beneath the scanhead. The LEDs 22a are angularly disposed relative to the vertical axis of the scanhead so that their respective light beams combine to illuminate the desired light strip defined by an aperture in the mask. The scanhead 18a also includes a photodetector 26a mounted directly over the center of the illuminated strip for sensing the light reflected off the strip. The photodetector 26a is linked to the CPU 30 through the ADC 28 for processing the sensed data as described above.

In the particular embodiment of the scanheads 18a and 18b illustrated in the drawings, each scanhead includes two pairs of LEDs and two photodetectors for illuminating, and detecting light reflected from, strips of two different sizes. Thus, each mask also includes two slits which are formed to allow light from the LEDs to pass through and illuminate light strips of the desired dimensions. More specifically, one slit illuminates a relatively wide strip used for obtaining the reflectance samples which correspond to the characteristic pattern for a test bill. In one embodiment, the wide slit has a length of about 0.500" and a width of about 0.050". The second slit forms a relatively narrow illuminated strip used for detecting the thin borderline surrounding the printed indicia on currency bills, as described above in detail. In one embodiment, the narrow slit 283 has a length of about 0.300" and a width of about 0.010".

In order to prevent dust from fouling the operation of the scanheads, each scanhead includes three resilient seals or gaskets 290, 291, and 292. The two side seals 290 and 291 seal the outer ends of the LEDs 22, while the center seal 292 seals the outer end of the photodetector 26. Thus, dust cannot collect on either the light sources or the photodetectors, and cannot accumulate and block the slits through

which light is transmitted from the sources to the bill, and from the bill to the photodetectors.

Doubling or overlapping of bills in the illustrative transport system is detected by two photosensors PS1 and PS2 which are located on a common transverse axis that is perpendicular to the direction of bill flow (see e.g., FIG. 22). The photosensors PS1 and PS2 include photodetectors 293 and 294 mounted within the lower support member 281 in immediate opposition to corresponding light sources 295 and 296 mounted in the upper support member 280. The photodetectors 293, 294 detect beams of light directed downwardly onto the bill transport path from the light sources 295, 296 and generate analog outputs which correspond to the sensed light passing through the bill. Each such output is converted into a digital signal by a conventional ADC converter unit (not shown) whose output is fed as a digital input to and processed by the system CPU.

The presence of a bill adjacent the photosensors PS1 and PS2 causes a change in the intensity of the detected light, and the corresponding changes in the analog outputs of the photodetectors 293 and 294 serve as a convenient means for density-based measurements for detecting the presence of "doubles" (two or more overlaid or overlapped bills) during the currency scanning process. For instance, the photosensors may be used to collect a predefined number of density measurements on a test bill, and the average density value for a bill may be compared to predetermined density thresholds (based, for instance, on standardized density readings for master bills) to determine the presence of overlaid bills or doubles.

In order to prevent the accumulation of dirt on the light sources 295 and 296 and/or the photodetectors 293, 294 of the photosensors PS1 and PS2, both the light sources and the photodetectors are enclosed by lenses mounted so close to the bill path that they are continually wiped by the bills. This provides a self-cleaning action which reduces maintenance problems and improves the reliability of the outputs from the photosensors over long periods of operation.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that it is not intended to limit the invention to the particular forms disclosed, but on the contrary,

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